$$SD_{combined} = \sqrt{\frac{I}{N}} = \left(\sum_{x=1}^{x=N} SD_x^2 + \sum_{x=1}^{x=N} SD_x^2 \right) \quad (1)$$

$SD_{combined}$ = Combined standard deviation of SO_2 emissions due to variation between factories and inaccuracy in measurements;
SD_s = Standard deviation of SO_2 emissions due to variation between the five factories;
SD_x = Standard deviation of SO_2 emissions due to inaccurate measurements in factory x;
x = Factory identification number;
N = Number of factories.

The $SEM_{combined}$ is computed by means of the following equation:

$$SEM_{combined} = \frac{SD_{combined}}{\sqrt{N}} \quad (2)$$

in which all variables equal those mentioned above, and the $SEM_{combined}$ represents the error of the mean SO_2 emission introduced by both the generalisation of the sample emission average to the emission average of all product P producing factories and inaccurate measurements. As can be seen in Table 3, the characteristics of the emission profile will change, depending on whether inaccuracy in combination with either variability ($SD_{combined}$) or uncertainty of the mean ($SEM_{combined}$) is taken into account.

Table 3: Characteristics of g SO_2 process emissions per kg product P

Emission	Factory A mean (sd)	Factory B mean (sd)	Factory C mean (sd)	Factory D mean (sd)	Factory E mean (sd)	Mean	SD_s	SEM_s	$SD_{combined}$	$SEM_{combined}$
g SO_2	16 (5)	20 (4)	18 (3)	25 (5)	30 (6)	21.8	5.7	2.5	7.4	3.3

Book Reviews

Environmental Life Cycle Analysis

Author: David F. Ciambrone
Publisher: Lewis Publishers (CRC Press LLC), Boca Raton, Florida 1997; also available by Springer Verlag Heidelberg. ISBN 1-56670-214-3. 145 pp. Price: US$ 65.-, GBP 52,-, DEM 135,-, CHF 123,-, ATS 986,-.

This is a curious book. I usually start reading a book from behind and in this case found appendices, e.g. with recycling codes of plastics, an enumeration of several US- environmental laws (3 pages), an appendix C which contains only one table with dubious heat values (upper? lower?) and a section "References" containing 17 (!) citations, the most recent one from 1995 (a self-quotation), the others typically from around 1990. Only four of these quotations refer to LCA (early SETAC, Battelle and Franklin). The index does not show entries on "functional unit" nor on "global warming".
After this disappointing start, I was gratified by very reasonable ideas put forward in the introductory chapters, which explain the need for life cycle thinking and analysis (the term assessment is used alternatively). In a short historical section, a paper by Harold Smith (World Energy Conference 1963) is mentioned in which the cumulative energy concept was presented. LCA is correctly distinguished from the "fence line approach" (gate-to-gate).
The author, a former manager, is well aware about the environmental problems connected with production processes and other life cycle steps, and he also recognises the need for some kind of impact assessment which he mostly calls "MANPRINT", although no clear operationalism is given. The focus of the book is on inventory analysis of industrial production processes starting with design and including recycling and waste management. The different phases are described in detail and is this part which might also be of interest for an experienced practitioner as a kind of checklist. The author, who is aware of the fact that many ad hoc decisions have to be made, has requested transparency in all steps. The allocation problem is addressed for the case of coproducts. Nevertheless, no rule is given for open loop recycling.

The functionality as a basis for comparison is not really addressed; it is not clear, for instance, whether or not the different bags compared in the standard example (plastic vs. paper) are really functionally equivalent. Here, as well as in other cases, the text is not rigorous enough and does not represent the state of the international discussion (ISO is not even mentioned). There are also inconsistencies in the definition of the system boundaries (Fig. 3-1) where the usable products leave the system which is only true for coproducts.
There are sentences in this book which I like, e.g. "Don't forget to talk to the people actually doing the work". On the other hand, there are omissions and many errors. In a list of "life cycle participants", the practitioner is missing. The energy content of a paper bag is reported to be 1,340,000 MJ on two occasions. The units are a mixture of US and SI-units; 1 kWh is given (again) as 3.61 MJ: dear friends in the US please note that an hour has exactly 3600 seconds, not 3610 and that 1 J = 1 Ws, hence 1 kWh = 3.6 MJ. In the comparison between paper and PE bags there are several misleading and redundant statements. Data sources are described in a vague and general manner which is of little (if any) help for the practitioner, e.g. "Local, regional wastewater control agencies, the U.S. EPA or the U.S. Army Corps of Engineers may have data on discharges to natural watersheds such as streams, rivers, lakes, and ocean outfalls". These general statements are in no case followed by a quotation.
The general impression about this book is that it is based on an old manuscript (somewhere between 6 and 8 years), which has not been updated and, inevitably in this rapidly evolving field, cannot represent the state of the art. The basic ideas are correct, however, and it would be desirable that managers and politicians would have at least this basic knowledge about the product/environment interplay. For the expert, as stated above, the inventory part may contain some useful information. The book is certainly not suited for someone wishing to learn LCA from the beginning.

Walter Klöpffer
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